STATE OF ILLINOIS
ILLINOIS COMMERCE COMMISSION

CENTRAL ILLINOIS LIGHT COMPANY d/b/a AmerenCILCO	)	
CENTRAL ILLINOIS PUBLIC SERVICE COMPANY d/b/a AmerenCIPS	)	07-0539
ILLINOIS POWER COMPANY d/b/a AmerenIP	)	
Approval of the Energy Efficiency and Demand-Response Plan.	)	

TESTIMONY OF CHRISTOPHER C. THOMAS ON BEHALF OF THE CITIZENS UTILITY BOARD

CUB Exhibit 1.0

December 14, 2007

ICC DOCKET NO. 07-0539

DIRECT TESTIMONY OF CHRISTOPHER C. THOMAS

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I. STATEMENT OF QUALIFICATIONS

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is Christopher C. Thomas. My business address is 208 S. LaSalle Street, Suite 1760, Chicago, IL 60604-1003.

Q. WHAT IS YOUR PRESENT OCCUPATION?

A. I am employed by the Citizens Utility Board ("CUB") as the Director of Policy. My duties include development of CUB's policy positions, filing expert testimony before the Illinois Commerce Commission ("ICC" or "Commission") on CUB's behalf, and management of the Policy Department. My responsibilities also include serving as CUB's voting representative to the PJM member committee and working to develop consumer sector positions within the MISO Advisory Committee.

Q. PLEASE SUMMARIZE YOUR PROFESSIONAL EXPERIENCE.

A. My professional career includes eight years as a utility regulatory economist. I started my career as a regulatory economist in the Telecommunications Department of the Missouri Public Service Commission ("MoPSC"). While with the MoPSC, I filed testimony or affidavits in 11 different dockets. I became a CUB employee in September 2004, and have filed testimony before the ICC in numerous dockets. CUB Exhibit 1.01, attached to this testimony, is a list of the dockets in which I have filed testimony and a brief description of the nature of each docket.

Q. PLEASE DESCRIBE YOUR EDUCATIONAL BACKGROUND.

A. I have a Bachelor's degree in Business Administration with a concentration in Finance and a minor in Economics from Truman State University, and a Master's degree in Economics and Finance from Southern Illinois University, Edwardsville.

II. PURPOSE OF TESTIMONY

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY?

A. The purpose of my testimony is to address Ameren's proposed Residential Direct Load Control program, which the company has proposed to meet the demand response standards of Section 12-103(c) of the Act. This section requires electric utilities to implement "cost-effective demand response measures to reduce peak demand by 0.1% over the prior year for eligible retail customers." 220 ILCS 5/12-103(c). There are two general problems with the Company's proposal:

1) Ameren's cost estimates are only assumptions, which are not based on the Company's own experience.

2) Ameren must maximize the value of the direct load control program and return any financial benefits to customers by modifying Rider EDR.

Q. WHAT IS AMEREN'S PROPOSED RESIDENTIAL DIRECT LOAD CONTROL PROGRAM?

A. Ameren proposes to implement an air conditioner cycling program for residential customers with central air conditioning units. This program is very similar to ComEd's

Nature First program, which has operated for a number of years in northern Illinois. Essentially, Ameren will install a switch on the compressor of each participant's central air conditioner. This switch allows Ameren to turn the compressor on and off for short periods of time on peak summer days (commonly referred to as cycling). In return, customers receive bill credits for participating in the program, depending on their level of participation. Cycling air conditioners reduces load during peak times and acts as a relief valve against stress on the distribution system. Using an air conditioner cycling program to reduce demand during peak times also reduces electricity prices.

Q. ARE YOU CONCERNED ABOUT THE IMPACT THAT DIRECT LOAD CONTROL WILL HAVE ON CUSTOMER COMFORT?

A. Of course. Customer comfort is one of CUB's foremost concerns. However, studies have found that direct load control can achieve significant peak load reductions without moving outside of the comfort zones established by the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) basic comfort guidelines. See CUB Exhibit 1.02 (Good Sense presentation, Slide 6); CUB Exhibit 1.03 (Jason Black Paper, Figure 5). These studies show that a cycling program may impact temperature levels within a structure by 1 to 3 degrees, well within the ASHRE guidelines. *Id.*

III. AMEREN'S PROPOSED COST ESTIMATES

Q. WHAT PROBLEMS HAVE YOU IDENTIFIED WITH AMEREN'S PROPOSED COST ESTIMATES?

A. Because Ameren has not done an air conditioner cycling program in the past, Ameren does not have experience with such a programs costs. Thus, Ameren's cost estimates are only assumptions. Additionally, as I will explain, there is an inconsistency between these assumptions and the company's proposed budget. Therefore, the Commission must ensure that the costs recovered through the Company's proposed Rider EDR are appropriate.

Q. HOW DO YOU KNOW THAT AMEREN'S PROPOSED COSTS FOR THE DIRECT LOAD CONTROL PROGRAM ARE ASSUMED?

A. In Ameren's Response to CUB Discovery Request 2.06 (CUB Ex. 1.04) the company stated:

> The incentive of $170 represents the assumed cost of $145 for the control switch and an assumed customer payment of $25. The $145 and $25 values were selected to be generally consistent with assumptions used for the ComEd Nature First Program. Ameren Response to CUB 2.06.

In Ameren's Response to CUB Discover Request 2.08 (CUB Ex. 1.05) the company stated:

> The budget is the sum of incentive and non-incentive program costs. Incentive program costs are equal to the $170 assumed per measure incentive and the estimated number of participants. Non-incentive program costs were set at 25% of incentive costs, essentially as a placeholder to test cost effectiveness. Ameren Response to CUB 2.08.

Ameren should explain its assumptions, and why they should apply to Ameren, more thoroughly.

Q. WHAT, SPECIFICALLY, IS INCONSISTENT WITH AMEREN'S BUDGET?

A. In response to CUB 2.08, shown above, Ameren states that it bases its budget on a $170 per customer incentive cost and a placeholder of 25% non-incentive costs. However, this methodology is not consistent with the budget contained on page 103 of Ameren Ex. 1.0. Table 1 below demonstrates the discrepancies:

TABLE 1: INCONSISTENCIES IN AMEREN'S BUDGET

	2008	2009	2010
New Switches (from Ameren Ex. 1.0, Pg. 103)	3,090	3,104	3,215
Total Switches	3,090	6,194	9,409
Switch Cost (from CUB DR 2.06)	$145	$145	$145
Participant Incentive (from CUB DR 2.06)	$25	$25	$25
Total Incentive Cost	$525,300	$604,930	$701,400
25% Non-incentive Cost	[illegible]	[illegible]	[illegible]
Total Incentive and Non-Incentive Cost	$656,625	$756,163	$876,750
Ameren Budget (from Ameren Ex. 1.0, Pg. 103)	$637,326	$851,820	$1,087,386
Inconsistency (Ameren Budget less Total Costs)	($19,299)	$95,658	$210,636

As Table 1 demonstrates, using the methodology Ameren identified in response to CUB 2.08, Ameren has under-budgeted costs in 2008 and over-budgeted in 2009 and 2010.

The Company should explain the discrepancy between the methodology provided in response to CUB 2.08 and the budget shown on page 103 of Ameren Ex. 1.0.

Q. HOW SHOULD THE COMMISSION DETERMINE IF THE COSTS PROPOSED BY AMEREN ARE APPROPRIATE?

A. The Company states that it will file monthly informational filings and submit informational annual audits in an annual report to the Commission. Because these filings are only informational in nature, the Commission should make it clear that the costs included in Ameren's proposed Rider EDR should include only Ameren's actual costs, exclusive of inflation or other projected asymmetrical costs. The Commission should ensure than any projected costs recovered through Rider EDR are offset by cost savings.

Q. WHY IS IT INAPPROPRIATE TO INCLUDE INFLATION IN THESE COST ESTIMATES?

A. All companies experience inflation through the rising cost of labor, healthcare, and materials and supplies. Companies also experience increased productivity that offsets the effects of inflation. Unfortunately, utilities often seek to include the effects of inflation in projected costs without incorporating productivity growth as well. According to the Bureau of Labor Statistics most recent release of "Productivity and Cost By Industry: Selected Service-Providing and Mining Industries, 2005," unit labor costs for power generation and supply utilities (NAICS number 2211 - which I understand to include electric power generation, transmission and distribution functions) actually fell by 3.7%

between 2004 and 2005. The Commission cannot include cost increases in a rider without the offsetting symmetric cost savings that occur through productivity gains. The Commission should make it clear in its Order, that Ameren is not entitled to include inflation in any costs to be charged to customers, and that costs included in Rider EDR should be symmetric. That is, Rider EDR costs should include both projected cost increases and cost savings.

IV. THE COMMISSION MUST DIRECT THE COMPANY TO MAXIMIZE THE DIRECT LOAD CONTROL PROGRAM'S VALUE AND RETURN ANY FINANCIAL BENEFITS TO CUSTOMERS

Q. HOW CAN AMEREN MAXIMIZE THE VALUE OF THE DIRECT LOAD CONTROL PROGRAM?

A. Direct load control programs such as the one Ameren has proposed in this docket displace the need to purchase additional energy, capacity, and potentially even ancillary services, to serve customers. In many RTO administered markets, participants can receive payments for the demand response achieved through their direct load control programs.

Q. ARE SUCH PAYMENTS AVAILABLE TO AMEREN'S DIRECT LOAD CONTROL PROGRAM?

A. Potentially. The Midwest ISO ("MISO") runs an ancillary service market that includes provisions for demand response to participate, although it is not clear exactly how that participation would occur. In addition, if MISO follows the trends established by more mature ISOs, such as PJM Interconnection, LLC, there will be energy and capacity revenues available for this program in the future.

Q. HOW CAN WE TELL THAT AMEREN DOES NOT INTEND TO RETURN ANY REVENUES GENERATED BY THE DIRECT LOAD CONTROL PROGRAM TO CUSTOMERS?

A. Ameren's proposed Rider EDR (Ameren Ex. 5.1) does not include any mechanism to flow revenues received from these programs back to customers. As I will discuss below, Ameren may be able to produce revenue by selling the energy, and capacity generated by these programs into future markets. These revenues must flow through to consumers. Thus, the Commission must add a factor to Ameren's proposed EDR Charge ("EDRC") that adds revenues received from programs into the calculation of the charge. ComEd included such a factor in its Rider EDA (Docket 07-0540, ComEd Ex. 1.0, Appendix F), and the following modified version of that language is appropriate for Ameren to include in its tariff:

> Factor RIC – Reimbursement of Incremental Costs, in $, that are equal to funds from any source other than the application of EDRC that the Company expects to receive that are associated with the applicable twelve (12) month period of an ICC approved energy efficiency and demand response plan, if any, directly related to the implementation of programs and not otherwise credited.

Inclusion of this factor would change the calculation of Ameren's EDRC as follows:

> EDRC = [(PC+RIC+ARA+ORA) / PE] x UF x [100/1]

Q. WHAT IF AMEREN CANNOT GENERATE ADDITIONAL REVENUE WITH RIDER EDR?

A. Until it is clear how demand response can participate in MISO's ancillary services market, the RIC factor that I have proposed to include in Ameren's Rider EDR may be zero. However, it is necessary to include this factor to account for revenues that may arise in the future. My understanding is that MISO's Demand Response Working Group is working to incorporate demand response resources into MISO's markets. The Commission should direct the utility to capture all available energy and capacity revenues from MISO administered markets, and from the yet to be formed Illinois Power Agency ("IPA") when, appropriate processes to purchase the capacity and energy value of demand response are instituted.

V. CONCLUSION

Q. PLEASE SUMMARIZE YOUR TESTIMONY.

A. Ameren's cost estimates are only assumptions, which are not based on the Company's own experience. Ameren should explain its assumptions more thoroughly. In addition, the Commission should make it clear in its Order that Ameren is not entitled to include inflation in any costs to be charged to customers, and that costs included in Rider EDR should be symmetric. That is, Rider EDR costs should include both projected cost increases and cost savings. The Company should explain the discrepancy between the methodology provided in response to CUB 2.08 and the budget shown on page 103 of

Ameren Ex. 1.0, and Ameren must maximize the value of the direct load control program and return any financial benefits to customers by modifying Rider EDR.

Q. DOES THAT CONCLUDE YOUR TESTIMONY?

A. Yes.

Docket Summary for Christopher C. Thomas

Illinois Commerce Commission Docket No.07-528
Commonwealth Edison Company, Petition for Approval of Initial Procurement Plan
On Behalf of: The Citizens Utility Board

Illinois Commerce Commission Docket No.07-527
Central Illinois Light Company, d/b/a Ameren CILCO; Central Illinois Public Service Company, d/b/a Illinois Public Service Company, d/b/a Ameren CIPS; and Illinois Power Company, d/b/a AmerenIP, Petition for Approval of Initial Procurement Plan
On Behalf of: The Citizens Utility Board

Illinois Commerce Commission Docket No.07-0242 (cons.)
North Shore Gas Company and Peoples Gas Light and Coke Company Proposed general increase in natural gas rates
On Behalf of: The Citizens Utility Board and the City of Chicago

Illinois Commerce Commission Docket No.07-0166
Commonwealth Edison Company Investigation pursuant to Section 9-250 of the Public Utilities Act of Rate Design
On Behalf of: The Citizens Utility Board

Illinois Commerce Commission Docket No.07-0165
Central Illinois Light Company, d/b/a Ameren CILCO; Central Illinois Public Service Company, d/b/a Illinois Public Service Company, d/b/a Ameren CIPS; and Illinois Power Company, d/b/a AmerenIP Investigation pursuant to Section 9-250 of the Public Utilities Act of Electric Rate Design
On Behalf of: The Citizens Utility Board

Illinois Commerce Commission Docket No.06-0800
Investigation of Rider CPP of Commonwealth Edison Company, and Rider MV of Central Illinois Light Company d/b/a AmerenCILCO, of Central Illinois Public Service Company d/b/a AmerenCIPS, and of Illinois Power Company d/b/a AmerenIP, pursuant to Commission Orders regarding the Illinois Auction
On Behalf of: The Citizens Utility Board

Illinois Commerce Commission Docket No. 06-0691 (cons.)
Central Illinois Light Company d/b/a AmerenCILCO, Central Illinois Public Service Company, d/b/a Ameren CIPS, Illinois Power Company d/b/a AmerenIP, Proposal to establish a new rider entitled Rider PRP – Price Response Program, (tariffs filed September 29, 2006)
On Behalf of: The Citizens Utility Board

Docket Summary for Christopher C. Thomas

Illinois Commerce Commission Docket No. 06-0617
Commonwealth Edison Company Proposed Revisions to Rate BES-H Basic Electric Service Hourly Energy Pricing
On Behalf of: The Citizens Utility Board and The City of Chicago

Illinois Commerce Commission Docket No. 06-0379
Citizen's Utility Board And the People of the State of Illinois Petition To Initiate Rulemaking With Notice and Comment for Approval of Certain Amendments to Illinois Administrative Code Part 280.
On Behalf of: The Citizens Utility Board

Illinois Commerce Commission Docket No. 06-0270
COMMONWEALTH EDISON COMPANY Petition of Commonwealth Edison Company For Approval Pursuant to Section 7-102 of the Public Utilities Act of the Entry into Certain Contracts Relating to Wind Generation and Approval Under Section 9-201 of a Tariff Concerning the Governor's Sustainable Energy Plan and the Illinois Commerce Commission's Resolution in Docket No. 05-0437.
On Behalf of: The Citizens Utility Board

Illinois Commerce Commission Docket No. 06-0070 (cons.)
CENTRAL ILLINOIS LIGHT COMPANY, d/b/a Ameren CILCO, CENTRAL ILLINOIS PUBLIC SERVICES COMPANY, d/b/a AmerenCIPS, and ILLINOIS POWER COMPANY, d/b/a AmerenIP Proposed General Increase For Delivery Services
On Behalf of: The Citizens Utility Board

Illinois Commerce Commission Docket No. 06-0027
Illinois Commerce Commission Vs. Illinois Bell Telephone Company - Investigation of specified tariffs declaring certain services to be competitive Telecommunications services.
On Behalf of: The Citizens Utility Board

Illinois Commerce Commission Docket No. 05-0597
Commonwealth Edison Company Proposed general increase in electric rates, general restructuring of rates, price unbundling of bundled service rates, and revision of other terms and conditions of service.
Testimony On Behalf of: The Citizens Utility Board and The City of Chicago

Illinois Commerce Commission Docket No. 04-0779
Nicor Inc. Proposed General Increase in Rates
Testimony On Behalf of: The Citizens Utility Board and the Cook County States Attorney

Docket Summary for Christopher C. Thomas

Illinois Commerce Commission Docket No. 04-0476
Illinois Power Company and Ameren Corp Proposed General Increase in Gas Rates
On Behalf of: The Citizens Utility Board

Missouri Public Service Commission Docket No. TR-2002-251
In the Matter of the Tariffs Filed by Sprint Missouri, Inc., d/b/a Sprint, to Reduce the Basic Rates by the Change in the CPI-TS as Required by Section 392.245(4), Updating Its Maximum Allowable Prices for Non-basic Services and Adjusting Certain Rates as Allowed by Section 392.245(11), and Reducing Certain Switched Access Rates and Rebalancing to Local Rates, as Allowed by Section 392.245(9) (Affidavit)
On Behalf of: Staff of the Missouri Public Service Commission

Missouri Public Service Commission Docket No. TO-2004-0207
In the Matter of a Commission Inquiry into the Possibility of Impairment without Unbundled Local Circuit Switching When Serving the Mass Market
On Behalf of: Staff of the Missouri Public Service Commission

Missouri Public Service Commission Docket No. IT-2004-0015
In the Matter of Southwestern Bell Telephone Company, d/b/a SBC Missouri's Proposed Revised Tariff Sheet Intended to Increase by Eight Percent the Rates for Line Status Verification and Busy Line Interrupt as Authorized by Section 392.245, RSMo, the Price Cap Statute
On Behalf of: Staff of the Missouri Public Service Commission

Missouri Public Service Commission Docket No. TT-2002-472/473
In the Matter of Southwestern Bell Telephone Company's Tariff Filing to Initiate Residential Customer Winback Promotion / In the Matter of Southwestern Bell Telephone Company's Tariff Filing to Extend Business Customer Winback Promotions
On Behalf of: Staff of the Missouri Public Service Commission

Missouri Public Service Commission Docket No. TO-2002-222
In the Matter of the Petition of MCImetro Access Transmission Services LLC, Brooks Fiber Communications of Missouri, Inc., and MCI WorldCom Communications, Inc., for Arbitration of an Interconnection Agreement With Southwestern Bell Telephone Company Under the Telecommunications Act of
1996.
On Behalf of: Staff of the Missouri Public Service Commission

Docket Summary for Christopher C. Thomas

Missouri Public Service Commission Docket No. TA-2001-475/TA-99-47
In the Matter of the Application of Southwestern Bell Communications Services, Inc., d/b/a SBC Long Distance, for a Certificate of Service Authority to Provide Interexchange Telecommunications Services within the State of Missouri / In the Matter of the Application of Southwestern Bell Communications Services, Inc., d/b/a Southwestern Bell Long-distance, for a Certificate of Service Authority to Provide Interexchange Telecommunications Services within the State of Missouri.
On Behalf of: Staff of the Missouri Public Service Commission

Missouri Public Service Commission Docket No. TO-2001-455
In the Matter of the Application of AT&T Communications of the Southwest, Inc., TCG St. Louis, Inc., and TCG Kansas City, Inc., for Compulsory Arbitration of Unresolved Issues With Southwestern Bell Telephone Company pursuant to Section 252(b) of the Telecommunications Act of 1996
On Behalf of: Staff of the Missouri Public Service Commission

Missouri Public Service Commission Docket No. TO-2001-439
In the Matter of the Determining of Prices, Terms and Conditions of Conditioning for xDSL-capable Loops
On Behalf of: Staff of the Missouri Public Service Commission

Missouri Public Service Commission Docket No. TT-2001-298
In the Matter of Southwestern Bell Telephone Company's Proposed Tariff PSC Mo. No. 42 Local Access Service Tariff, Regarding Physical and Virtual Collocation
On Behalf of: Staff of the Missouri Public Service Commission

Missouri Public Service Commission Docket No. TT-2000-527/513
In the Matter of the Application of Allegiance Telecom of Missouri, Inc., CCMO, Inc. d/b/a Connect!, DSLnet Communications, LLC, KMC Telecom III, Inc. and New Edge Network, Inc. for an Order Requiring Southwestern Bell Telephone Company to File a Collocation Tariff / In the Matter of the Joint Petition of Birch Telecom of Missouri, Inc. for a Generic Proceeding to Establish a Southwestern Bell Telephone Company Collocation Tariff Before the Missouri Public Service Commission
On Behalf of: Staff of the Missouri Public Service Commission

Missouri Public Service Commission Docket No. TO-98-329 In the Matter of an Investigation into Various Issues Related to the Missouri Universal Service Fund
On Behalf of: Staff of the Missouri Public Service Commission

ICC Docket 07-0539
CUB Ex. 1.02

Demand Response Programs

New Considerations, Choices, & Opportunities

An Illustrative GoodCents *Direct* Program Design

A/C Cycling During Control Event

Expected Number of Control Hours 150

Expected Number of Control Events 50

Cycling Option	Minutes Off	Minutes On	% of Time A/C Off	Change in Customer's Comfort Level	kW Demand Response	Annual Incentive Payment
1	6.00	24.00	20.00%	No Noticeable Change	0.40	$6.00
2	7.50	22.50	25.00%	No Noticeable Change Likely	0.50	$7.50
3	10.00	20.00	33.33%	1° Change in Temperature	0.80	$12.00
4	15.00	15.00	50.00%	2° Change in Temperature	1.20	$18.00
5	20.00	10.00	66.67%	3° Change in Temperature	1.60	$24.00
6	22.50	7.50	75.00%	4° Change in Temperature	1.75	$26.25
7	24.00	6.00	80.00%	5° Change in Temperature	1.90	$28.50

Example Control Periods

Winter:	5:00 a.m. to 7:00 a.m.	7:00 a.m. to 9:00 a.m.	8:00 p.m. to 10:00 p.m.
Summer:	2:00 p.m. to 4:00 p.m.	4:00 p.m. to 6:00 p.m.	6:00 p.m. to 8:00 p.m.

Control Event "Opt-Outs" per Year = 3

Demand Response as a Substitute for Electric Power System Infrastructure Investments

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Abstract – This paper investigates the system-wide implications of regulatory policies to promote demand response as a substitute for investments in system capacity (generation, transmission, and distribution). Investments in demand response technologies, such as smart thermostats for thermal energy storage, have the potential to improve the efficiency of operations and investments in the electric power system. Reducing the magnitude of demand fluctuations will allow the utilization of the generation, transmission, and distribution systems to be increased and the levels of ancillary voltage and frequency support and reserves reduced. An analysis of the long term effects of demand response on electricity pricing and generation investment is modeled. This analysis enables a general comparison of the potential for avoided costs in generation, transmission, and distribution that could be expected from active regulatory support of demand response investments.

Introduction

This paper investigates the potential for demand response to provide a substitute for capacity investments. Large scale implementation of demand response is modeled to determine the potential impact on capacity investments. The paper focuses on demand response at the residential level, which is typically discounted in terms of its potential size and perceived cost effectiveness. This paper attempts to present a case for the potential for residential demand response. Section 1 of the paper outlines the potential of demand response to reduce peak loads via thermal storage or load shifting. Section 2 contains an example illustrating the potential for thermal storage. Section 3 briefly explores the issues associated with implementing large scale demand response. Section 4 presents the results from simulations to determine the effects of large scale demand response on long term generation capacity. Section 5 illustrates the potential for demand response to substitute for investments in transmission capacity. Section 6 gives a brief overview of secondary benefits from demand response. Section 7 explores areas for future research.

I. Potential for Thermal Storage and Load Shifting

Innovations in control and communications technologies enable the creation of relatively low cost demand response schemes. A significant portion of peak demand can be shifted using these technologies given the proper regulatory and market structures. Past studies of the potential for demand response typically involved studies of consumer reaction to real time or time of use pricing without including the technologies to facilitate demand response. Several utilities currently have successful demand response programs that demonstrate the potential for peak shaving. The majority of these programs focus on large consumers. There is significant potential for peak shaving amongst smaller, residential consumers, however, that could be realized with the proper incentive schemes.

Electricity demand is indirect demand. Consumers do not actually demand electricity itself, but the services provided by equipment that uses electricity. Electricity demand can be differentiated by demand for power and demand for energy. Demand for power is instantaneous, while demand for energy is not. Energy based demand can be utilized as a storage mechanism for electric power. In addition, the services provided by equipment which demands power rather than energy are not time dependent in many cases.

A sub category of power demand consists of deferrable load. Washers, dryers, dishwashers, and possibly electric ovens are examples of appliances that have deferrable load. Consumers often are not concerned with the exact times that such appliances run, as long as it is within a certain interval. This presents an opportunity for deferring the power consumption by these appliances from peak to off peak time periods – especially if programmable controls are available to automate the deferral. Although these appliances typically make up a small portion of the total residential load due to their intermittent usage, they do consume significant amounts of power while running and therefore offer the potential for significant peak shaving whenever they can be shifted to off peak consumption.

Energy Based load consists of air conditioners, refrigerators, water heaters, and electric space heaters. These provide service based on thermal transfer (heat or cooling). As such, consumers are indifferent to the actual time that this equipment runs, as long as the temperature remains within a certain range. By intelligently controlling consumption, the desired temperature range can be utilized as a thermal storage medium, and therefore as an indirect electricity storage method.

Energy based load accounts for nearly 50% of total household consumption. This represents a very large potential for load shifting in order to reduce peak demand by utilizing thermal storage. Air conditioning accounts for over 20% of household electricity usage in the United States. Air conditioning load is also highly peak coincident, since summer peaks are almost entirely caused by air conditioning load. "Residential and commercial air conditioning load represent at least 30% of the summer peak electricity loads". [2]

Refrigeration accounts for over 10% of household electricity usage [2]. The load pattern of a refrigerator involves cycling over short time periods, on the order of minutes, which is relatively smooth between hours. This load profile is a result of the thermal characteristics of refrigerators and the desire for minimizing temperature deviations.

The storage time for a refrigerator is therefore too short to adequately allow for inter-hour load shifting. It is possible, however, to utilize for short term load reductions such as frequency control or possibly for VAR compensation. Refrigerators may also be integrated into protections schemes – they could "trip" much like circuit breakers in response to voltage sags and prevent higher level outages.

Thermal storage programs typically involve the use of chillers to create ice during off-peak hours that is then melted during peak hours to offset air conditioning load. [8] Chillers are installed only at larger load sources due to costs and economies of scale. Although it is possible that this technology could be expanded to the mass consumer market, it would involve the installation of significant equipment at the household level. A simpler method of thermal storage that can be adopted at the household level utilizes the internal air temperature of the home to store energy. By intelligently cycling air conditioners, while maintaining temperatures within a comfort zone instead of at a single setting, significant load can be shifted from peak hours. Such a scheme can also be applied to electric water heaters and electric heat.

II. Thermal Storage Example

The following example illustrates the potential for load shifting from thermal storage using air conditioning. The example utilizes a simple control scheme, based on the methodology outlined in the paper by Constantopoulos, Schweppe, and Larsen [1] and the optimization method developed by Daryanian [10]. Day ahead pricing data from the PJM system from July 8, 2003, along with Temperatures from Philadelphia, Pa are used as inputs to the model. The objective is to control the output of a residential air conditioning system for optimal cost savings. The result provides the potential economic savings from employing such a control scheme, as well as the resultant reductions in peak load power usage. Hourly pricing at the retail level is necessary for consumers to benefit from this thermal storage scheme.

The consumer's objective is to minimize the cost of air conditioning while maintaining the indoor air temperature within a certain range.

$$Min_e C_{ac} = \sum_i P_i * q_i \qquad (1)$$

s.t.

$$0 \le q_i \le q^{\max}$$

$$T^{\min} \le T_i \le T^{\max}$$

where:

$T^{min} = T^{ideal} - d$

$T^{max} = T^{ideal} + d$

d = Acceptable temperature deviation

q_i - energy (kWh) consumed for air conditioning in hour i.
P_i - price of electricity ($/kWh) in hour i.
q^{max} - Maximum power output of Air conditioner

The hourly household temperature, T, is determined by:

$$T_{i+1} = \varepsilon T_i + (1-\varepsilon)(T^o - \eta^* q_i / A) \qquad (2)$$

TABLE 1. Parameters and Values of Residential AC Control Model

Variable	Value	Description
T_0	75	Initial temperature (°F)
η	2.5	Efficiency of AC (COP)
q_i		Power output of AC in hour i
q_{max}	3.5	Maximum power output of AC (KW)
E	0.93	System inertia
T^o		Outside Temperature (°F)
A	0.14	Thermal Conductivity (KW/°F)
T_d	75°	Desired household Temp (°F)
D	2°	Maximum acceptable Temperature Deviation (°F)

**Parameter values from [1 and 5]*

The optimization assumes that temperature variations within ± 2° F of the thermostat set point do not result in loss of consumer utility – this deviation is well within the 7° F comfort zone established by the ASHRAE Handbook (See Figure below).

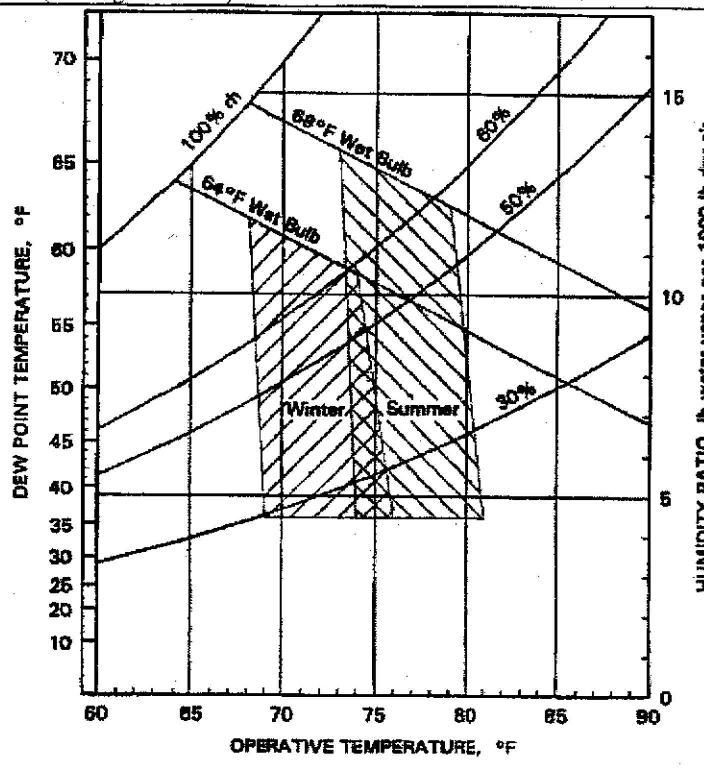


Fig. 5 ASHRAE Summer and Winter Comfort Zones
(Acceptable ranges of operative temperature and humidity for people in typical summer and winter clothing during primarily sedentary activity.)

Table 2 compares the results of applying a load control scheme to the AC versus the base case of allowing the AC to run on a single thermostat setting. It is assumed that the consumer is indifferent to indoor temperature fluctuations between 73° and 77°F ($T^{ideal} = 75°$, d = 2°)

Table 2. Normal vs. Controlled Air Conditioning Schemes

Date	8-Jul-03		Normal Cycling			Load Control		
Hr	Price ($/MWh)	Temp (outside)	Temp (inside)	Output (KWh)	Cost (mils)	Temp (inside)	Output (KWh)	Cost (mils)
1	$ 32.43	76	75.0	0.09	2.92	75.1	0.00	0.00
2	$ 24.23	78	75.0	0.31	7.51	75.3	0.00	0.00
3	$ 22.34	77	75.0	0.20	4.47	75.4	0.00	0.00
4	$ 21.43	75	75.0	0.00	0.00	75.4	0.00	0.00
5	$ 21.41	75	75.0	0.00	0.00	73.0	3.35	71.65
6	$ 23.45	74	74.9	0.00	0.00	73.0	0.09	2.11
7	$ 30.55	75	74.9	0.00	0.00	73.0	0.20	6.11
8	$ 39.65	77	75.0	0.10	4.16	73.0	0.40	15.86
9	$ 49.66	79	75.0	0.40	19.86	73.0	0.60	29.80
10	$ 58.45	82	75.0	0.70	40.92	73.0	0.90	52.61
11	$ 68.55	85	75.0	0.99	67.86	73.0	1.19	81.57
12	$ 82.31	84	75.0	0.90	74.08	73.0	1.10	90.55
13	$ 92.16	85	75.0	0.99	91.24	73.5	0.53	48.98
14	$ 105.32	87	75.0	1.21	127.44	74.4	0.00	0.00
15	$ 113.13	89	75.0	1.41	159.51	75.4	0.00	0.00
16	$ 118.23	88	75.0	1.30	153.70	76.3	0.00	0.00
17	$ 126.77	86	75.0	1.10	139.44	77.0	0.00	0.00
18	$ 118.94	86	75.0	1.10	130.84	77.0	0.90	107.05
19	$ 93.85	86	75.0	1.10	103.23	77.0	0.90	84.46
20	$ 83.79	85	75.0	0.99	82.95	77.0	0.79	66.19
21	$ 79.89	83	75.0	0.79	63.11	77.0	0.59	47.13
22	$ 69.03	83	75.0	0.79	54.53	77.0	0.59	40.73
23	$ 48.95	81	75.0	0.60	29.37	77.0	0.40	19.58
24	$ 43.72	81	75.0	0.60	26.23	75.0	3.26	142.39
			Totals -	15.67	1,383.38		15.79	906.77

Figure 2 below compares the controlled versus uncontrolled air conditioning consumption. The peak reduction in consumption is clear from the graph. Figure 3 illustrates the effect of pre-cooling to enable the reduction in peak consumption. When using thermal storage, the air is cooled (energy is stored) to the minimum temperature just prior to off peak hours and then allowed to rise during the peak hours (storage is discharged).

Figure 2. Comparison of Controlled to Uncontrolled Consumption

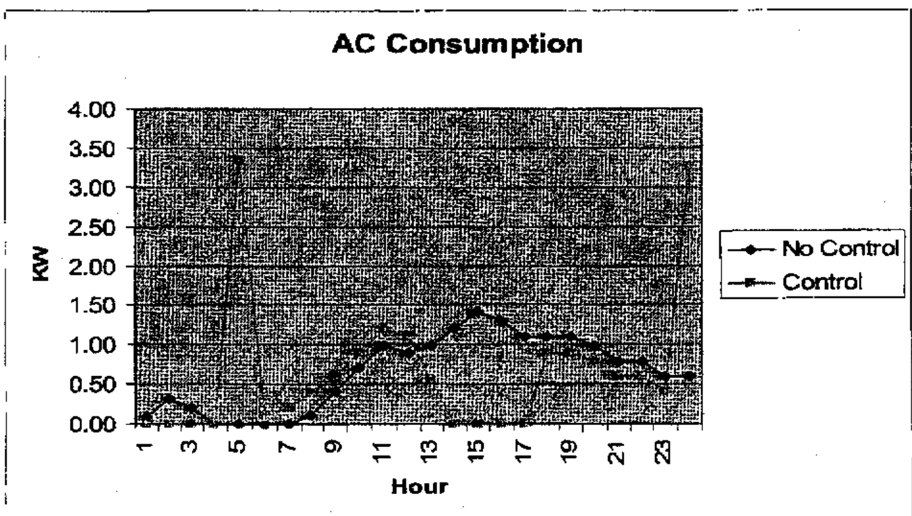
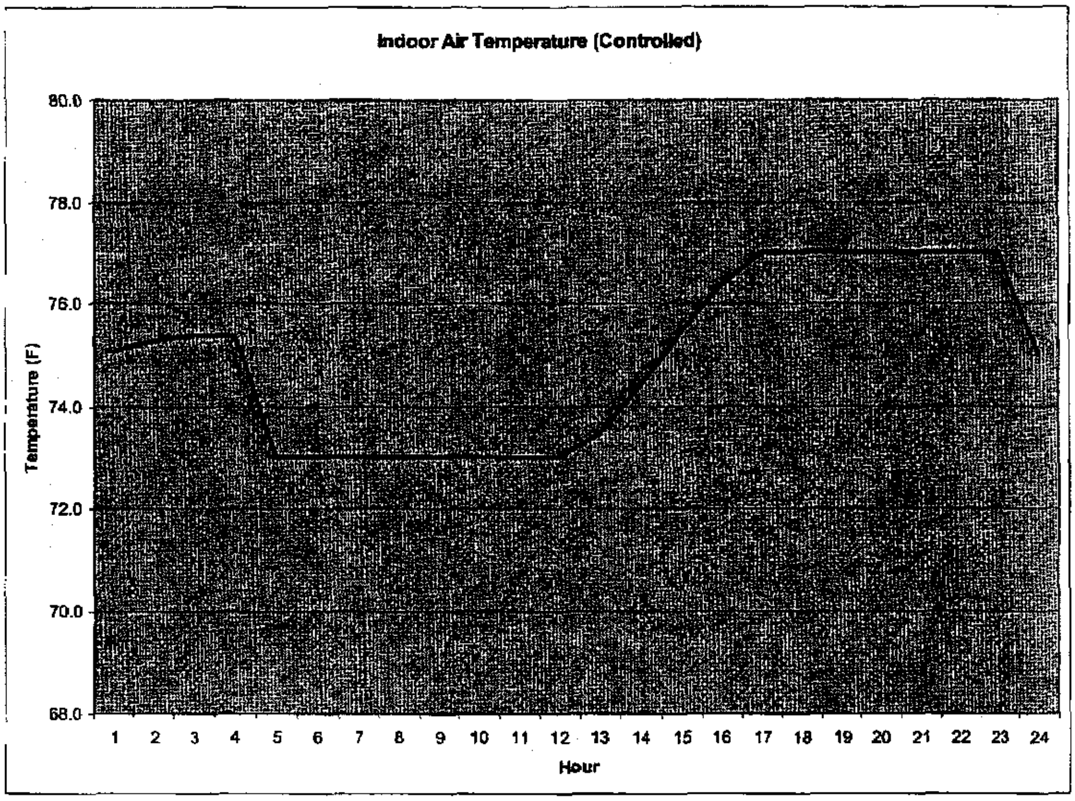


Figure 3. Indoor Air Temperature for Controlled Thermal Storage



As shown, during the five highest price hours of the day (hours 14-18), an 85% reduction in peak demand for air conditioning can be achieved by load shifting without moving outside the maximum temperature deviation. There is, however, a moderate increase in consumption in the hours before and immediately after the peak hours; with the highest consumption at beginning and end of the control period. The overall energy consumption increases very slightly, but the customer reduces their costs by over 33% for the day. The thermal storage control scheme enables significant savings and peak reductions while maintaining comfort. The system wide effects of large scale implementation of thermal storage are explored in subsequent sections.

III. Implementation

Implementing demand response requires investments at both the system and the customer levels. At the system level, the communications, metering, and billing infrastructure is necessary to facilitate a demand response program. Several utilities have invested in this infrastructure with the costs being included in their rate bases. Incentives for utilities to make such investments are limited because of potential lost revenues from reduced demand as well as the potential for eventual competitive entry facilitated by automation of metering and billing functions.

Real time metering capability is necessary to allow for hourly monitoring and billing of power consumption. Without such capability, it is not possible to allocate the costs/benefits of demand response directly to consumers. Two-way communications systems for sending price or other control signals to consumers and receiving near real time load information to assess charges are necessary. The ubiquity of internet communications and the relatively small bandwidth required significantly reduce the costs of implementing such communications systems. Programs in Florida Power and Puget Energy that utilize real time metering along with programmable thermostats currently charge less than $5 per customer per month for participants in their demand response programs [4]. Economies of scope may allow such costs to be reduced significantly.

Utilities must significantly upgrade their billing systems to enable near real time charges and to manage the much larger degree of information flows. The information will also enable utilities to have a much greater knowledge of system conditions and should improve their ability to forecast load.

Information programs are necessary in order to educate consumers on the potential benefits and methodologies of demand response programs, including but not limited to – thermal storage, hourly pricing, metering and control equipment. Studies have shown that such programs can be effective at inducing consumers to change their consumption behavior even without price signals. [14,15,16,17,18]

Large scale demand response can be implemented with either distributed or a coordinated control. Distributed demand response allows consumers to make their own consumption/response decisions based on incentives provided by the utility/Load Serving Entity/system operator. These incentives can include pricing schemes such as real time pricing, time of use pricing, critical peak pricing, or demand bidding. Consumers receive a price signal and respond accordingly. Studies of pricing programs have found limited response (typically with elasticities on the order of –0.1 [16]). The majority of these studies, however, did not provide enabling technologies to the customers. Programs that do provide enabling technologies have found significant potential, however most of these programs fall under the coordinated type of DR below. [4]

Utilities or system operators coordinate several current demand response programs. In these programs, customers agree to reduce load at the direction of the utility. The contract will often include a limit to the number of hours the utility may declare a demand reduction event, and allow the demand to ignore the event at the cost of paying a penalty. Such programs enable the utility to predict the demand response and to attempt to coordinate the DR with the system conditions. The limitations include a limited number of hours, the lack of incentives for DR in non-event hours, and the lack of investment in true peak shifting equipment since most participants simply shut down all or part of their load in response to an event.

IV. System Wide Effects of Demand Response

This section examines the effects of large scale implementation of the thermal storage scheme outlined above. The individual case assumes that prices are unchanged by the actions of a single household. This assumption will hold in general, but when a sufficient number of consumers are participating in thermal storage market prices will be affected. A non-linear dynamic simulation model was used to evaluate the long run effects on market prices, generation capacity, and consumer savings from widespread adoption of thermal storage technologies.

The model uses data from the PJM system for the year 2003. The average air conditioning consumption in PJM is 640 KWh/yr [2]. The model uses a simple generation investment heuristic based on segment revenues to determine the effects of large-scale implementation of demand response on generation capacity. Consumers adopt the thermal storage according to their potential savings and awareness of the technology (via wor dof mouth). In addition, the model includes long term demand elasticity to include the rebound effect in the analysis.

The model segments the electricity market into base-load (18% of hours), intermediate (68% of hours), peak (13% of hours), and critical peak segments (1% of hours). Results from the optimization model outlined above were used as inputs to determine the amount of load shifted by each consumer from peak and critical peak hours to intermediate hours. A piecewise linear supply curve (See Figure 4) is used to determine the market clearing price; each segment is represented by the supply function. This curve was derived from the aggregate load and price data from PJM.

Figure 4 also shows the long term effects on the aggregate supply curve of implementing large scale demand response. The supply curve becomes steeper as peak load generation capacity is reduced due to a reduction in peak load. This mitigates the long term price savings seen by customers who do not participate (free riders) in demand response. On the other hand, the expected diminishing returns as more and more consumers participate, while still a factor, are also mitigated somewhat. It must be noted that even though the curve is steeper, the peak prices, on average, will be reduced significantly (nearly 25%) except for in the few critical peak hours when demand is highest.

Figure 4. Supply Curve with and without Load Shifting

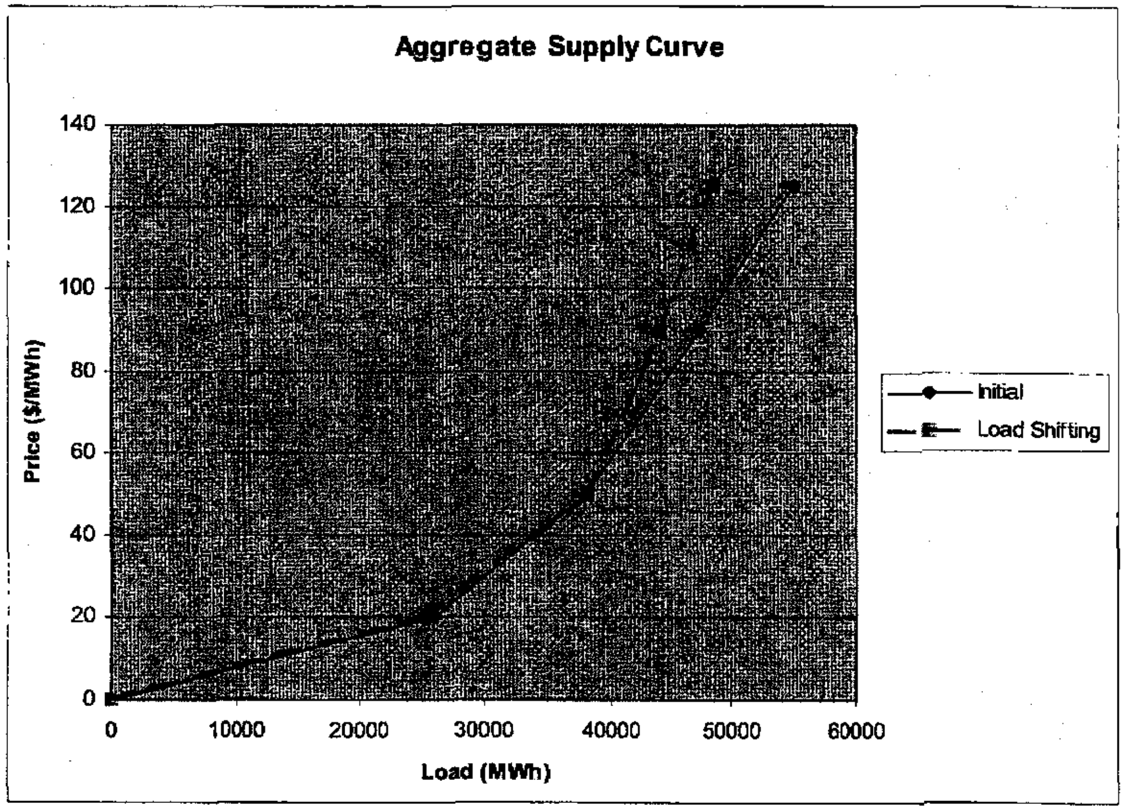


Figure 5. Generation Capacity by Sector

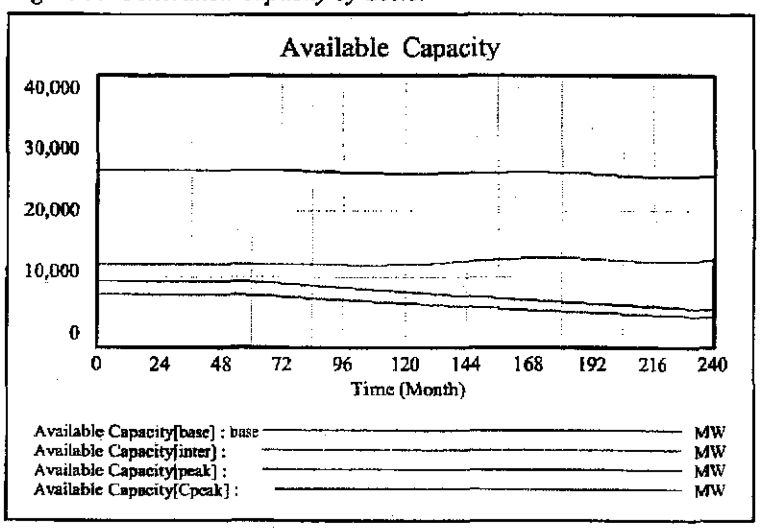
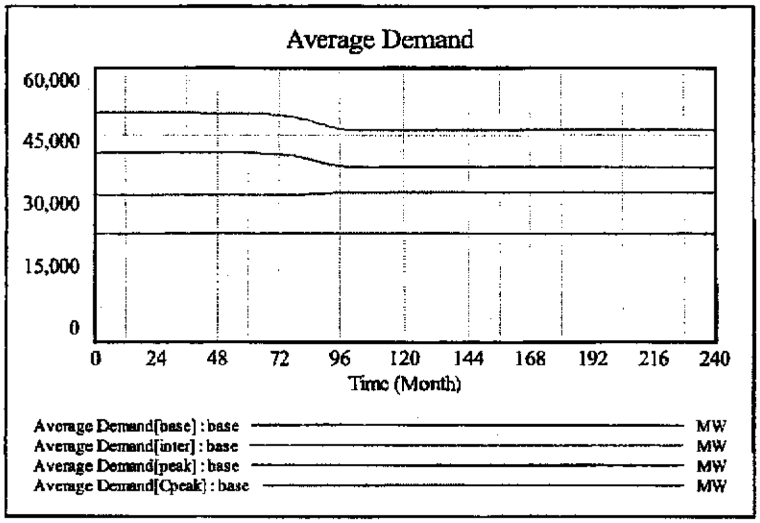


Figure 6. Average Hourly Demand by Segment



The results of the model indicate that demand in peak and critical peak hours is reduced by 8% (see Figure 6). System generation capacity is reduced by 12%. Base generation capacity decreases by 2%, intermediate capacity increases by 7% and peak capacity is reduced by 29%. Intermediate capacity increases due to a combination of higher utilization and increased prices in intermediate hours.

Because of diminishing returns, it is only cost effective for 25% of users to participate in load shifting. At this point, the costs of investing in the control equipment exceed the benefits of load shifting.

The model shows that the savings resulting from thermal storage are sufficient (in the PJM system) to cover the individual costs of installation, but not the system costs. Since all consumers benefit from the demand response program, it is not unreasonable to socialize the system costs. In addition, the externalities may prove large enough to justify some subsidization of the individual costs. Non-participants will receive the benefits of reduced costs and may otherwise free ride on the investments of participants.

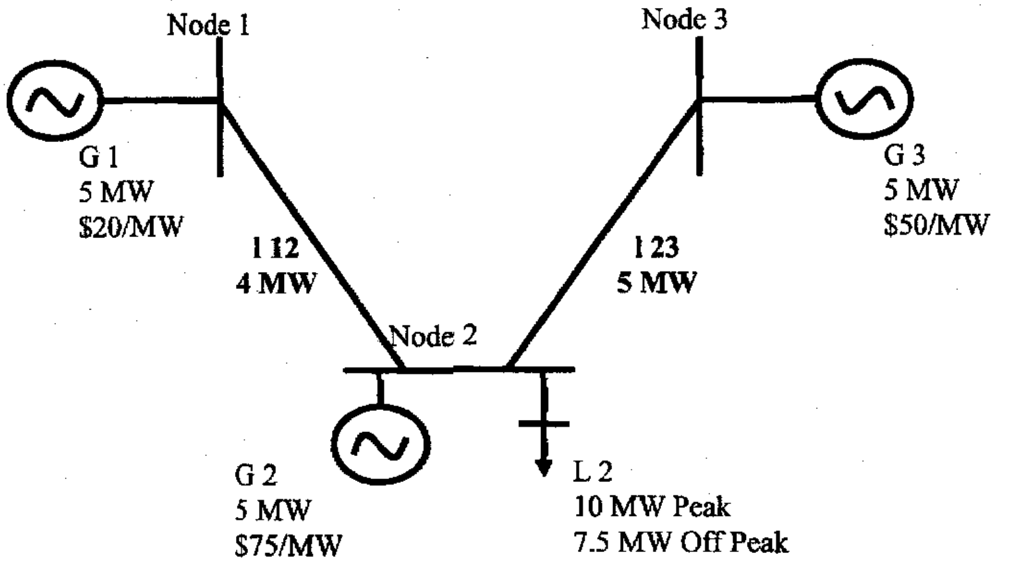
V. Investment Substitution with Demand Response

Reducing the peak load will directly impact the required transmission capacity since the system is built for the peak. The overall utilization of lines will also increase as the peak is reduced and the load smoothed. This will increase flow-based revenues for transmission companies, but will also reduce congestion charges.

Demand response also has significant potential to reduce the need for ancillary services. By smoothing the overall system load and shifting reactive power demand away from system peak loading, thermal storage will reduce the need for ancillary services such as VAR compensation, frequency control, and reserves. In addition to reducing the need for ancillary services from load shifting, demand resources can be utilized directly for VAR compensation, frequency control, and short term reserves.

As with traditional demand side management programs, investments in the infrastructure for demand response should include analysis of the avoided costs (least cost planning). The difference is that often investments in demand response infrastructure, such as real time metering, are an indirect method of reducing demand and therefore may be difficult to quantify. The infrastructure enables demand response and is a necessary but not sufficient component of demand response. The components of consideration should include reductions in spot prices (including LMP), the elimination of capacity expansion in generation, transmission, and distribution, and reductions in reserves and ancillary services. The value of demand response for increasing reliability is significant and should be included as well.

Figure 7. Example 3 node system



In the following example, the simple three-node system above is used to illustrate the potential avoided costs of transmission or generation expansion from DR.

In this system, the peak price will be $75/MW with 4MW from G1, 5 MW from G3, and 1 MW from G2. The off peak price will be $50/MW with 4MW from G1 and 3.5 MW from G3.

With 10% DR (assuming .5MW shifted before and .5 MW shifted after the peak time period) the load will be 9 MW peak and 8 MW off peak. Under these conditions, the price will be $50/MW in both peak and off peak hours.

For N-1 security criteria to be satisfied, the system would have to add 1 MW of capacity either to line 1-2 or to generator 2 without demand response. Demand response allows the N-1 criteria to be satisfied with no additional investments. This illustrates the value of demand response for improving system reliability. Demand response can also be used in contingency/emergency situations to shed load without major service disruptions, which would be a significant improvement over rolling blackouts.

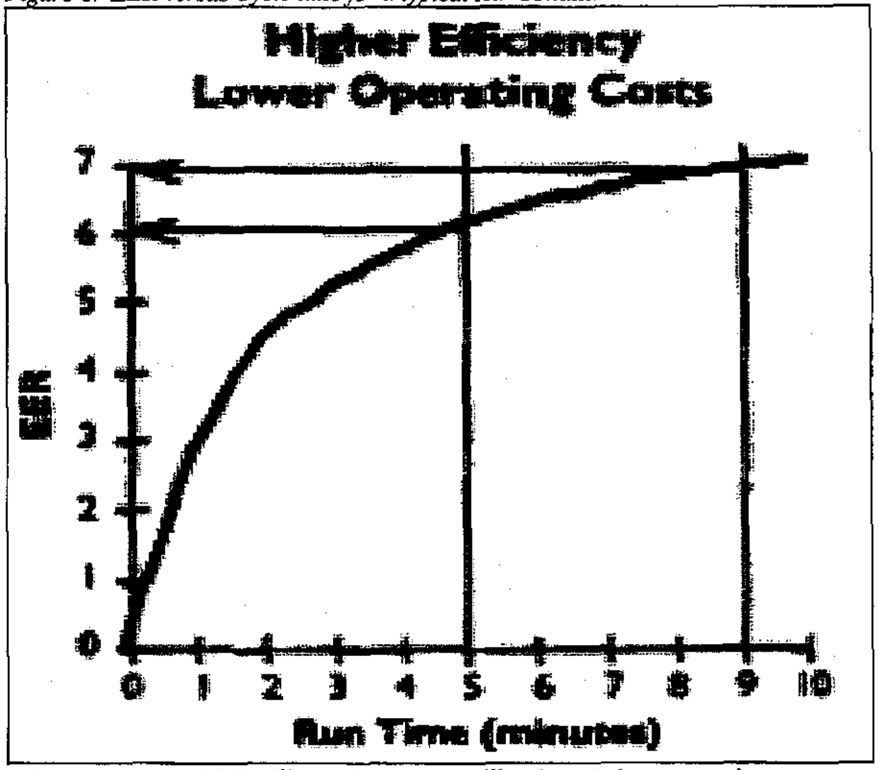
This example demonstrates the ability for demand response to substitute for capacity investments. The concept of avoided costs and least cost planning has been used for demand side management programs for many years. Typically the analysis of demand response programs includes only the direct economic savings from reductions in peak consumption. The indirect savings resulting from investments in infrastructure to support demand response, including reliability improvements and capacity substitution, should be incorporated in analysis of such investments.

VI. Additional Potential Benefits

There are multiple secondary benefits associated with technologies required for implementing demand response. These include improved efficiency of consumption, better customer service, and the potential for additional services.

The thermal control scheme will increase the cycle time of the air conditioner, which will also increase the efficiency and result in improved humidity reduction. The Energy Efficiency Ratio, EER (Btu/Wh) for air conditioners increases with cycle time, as does the amount of moisture that condenses and is collected. [12] (See Figure 8).

Figure 8. EER versus Cycle time for a typical Air Conditioner



It is likely that consumers with intelligent thermostats will reduce their consumption even more than the simple load shifting scenario outlined above. With greater control over temperatures and easier programming methods, consumers will be much more likely to allow their air conditioners to idle while they are away from home, thus possibly saving a great deal of electricity.

The automated metering systems also enable faster, more accurate fault detection since utilities can isolate the locations of faults as soon as they occur. They also increase customer service by providing more accurate billing and real time updates on changes to load. Additional services enabled by the metering and communications infrastructure include home security services and the bundling of water and natural gas metering.

Typical demand resopnse evaluations focus primarily on the avoided costs from reductions of peak prices. Additional savings are available from alleviating transmission congestion and eliminating the necessity of additional investments. Large Scale Demand response utilizing thermal storage has the potential to significantly increase efficiency of the electric power system and reduce the overall infrastructure capacity.

VII. Future Research

There are several areas of future research necessary to determine the long-term implications of large-scale adoption of demand response technologies. Research is necessary in engineering, economics, and political/social science. This research can be conducted through a combination of laboratory simulation and monitoring of ongoing implementations by innovative utilities.

In engineering, possible transient stability issues resulting from simultaneous action by loads in response to discontinuous pricing periods (currently hourly) should be investigated. The magnitude of complementary benefits such as increased efficiency from extending cycle times can also be determined. In addition, development of control algorithms that are cost effective, easily implemented, acceptable and understandable for residential consumers is a precursor for large-scale adoption. Methods to integrate demand response for ancillary services including frequency control, VAR support, and reserves also need further development. [6,11] Protection schemes that integrate demand response have significant potential and should be pursued as well. Line losses will be reduced in the short term as demand response reduces loading, but may increase in the long term if overall utilization is increased due to higher load factors.

Open research issues in economics include: Determination of the costs of information and education programs to promote consumer acceptance of demand response technologies; Further studies of the potential savings to include reductions in market power and the real options value of response technologies; determination of the magnitude of rebound effects from reduced prices and whether such effects are more or less peak coincident than current demand profiles; Determination of the long term effects on investment in generation, transmission, and distribution, including the possibility of stranded assets; Evaluation of market clearing mechanisms and the potential for instability or oscillatory behavior due to lumpy response behavior; Evaluation of various market designs to determine the incentives for investments in demand response .

Political and Social research on coalition formation, stakeholders and status quo bias, regulatory support/capture and uncertainty, and consumer behavior can determine the conditions and incentive structures necessary to promote large scale implementation/adoption of demand response technologies.

Demand response technologies have the potential to dramatically change the operation of the electric power system and to increase the efficiency of capital investments. Further research can help determine stable pathways to integrate demand response into the current system architecture.

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AmerenCILCO's, AmerenCIPS', and AmerenIP's Response to Citizens' Utility Board (CUB) Data Requests ICC Docket No. 07-0539 Approval of Energy Efficiency and Demand Response Plan

CUB 2.06 Provide all studies, surveys, data, and other documentation supporting the incentive strategy of $170 per kW of demand response as shown on page 103 of the Ameren Illinois Utilities Energy Efficiency and Demand-Response Plan.

Response: The incentive of $170 represents the assumed cost of $145 for the control switch and an assumed customer payment equivalent to $25. The $145 and $25 values were selected to be generally consistent with assumptions used for the ComEd Nature First Program.

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AmerenCILCO's, AmerenCIPS', and AmerenIP's Response to Citizens' Utility Board (CUB) Data Requests ICC Docket No. 07-0539 Approval of Energy Efficiency and Demand Response Plan

CUB 2.08 Provide all studies, surveys, data, and other documentation supporting the estimated budget shown on page 103 of the Ameren Illinois Utilities Energy Efficiency and Demand-Response Plan.

Response: The budget is the sum of incentive and non-incentive program costs. Incentive program costs are equal to the $170 assumed per measure incentive and the estimated number of participants. Non-incentive program costs were set at 25% of incentive costs, essentially as a placeholder to test cost-effectiveness.

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